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Summary

The goal of our research is to develop practical models and *efficient* algorithms to analyze and evaluate the reliability/availability/maintainability of complex systems in which component failures are statistically dependent and each component is subject to degradations before complete failure. We have developed the Event-Based Reliability Model (EBRM) for the reliability modeling and analysis of real systems in which component failures are statistically dependent. Most existing reliability models assume that system component failures are statistically independent. This assumption, though it greatly simplifies the problem, is often not valid, and the result is usually an overestimation of network reliability. We have also developed a model to approximate the reliability of systems with multimode components. Previous research on reliability has been focused on models which assume that each component may be in one of two modes, namely, operative or failed. In real life, a component may undergo degradations in performance before a complete outage, and will therefore operate in more than two modes. More *recently*, we have developed the Cause-based Multimode Model (CBMM), which allows one to consider failure dependencies of components which are subject to degradations. The model is very flexible and general and has physically meaningful parameters. Practical methods to approximate and bound network reliability and performance measures have been developed, based on a state enumeration approach. Most recently, we have developed a path-based approach to efficiently approximate reliability of systems having a path structure. Tests on representative examples have shown that the path-based approach can reduce the processing time by orders of magnitude.

BASIC RESEARCH IN RELIABILITY
FOR REAL SYSTEMS

Annual Technical Report

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AFOSR-88-0259

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Summary

The goal of our research is to develop practical models and efficient algorithms to analyze and evaluate the reliability/availability/maintainability of complex systems in which component failures are statistically dependent and each component is subject to degradations before complete failure. We have developed the Event-Based Reliability Model (EBRM) for the reliability modeling and analysis of real systems in which component failures are statistically dependent. Most existing reliability models assume that system component failures are statistically independent. This assumption, though it greatly simplifies the problem, is often not valid, and the result is usually an overestimation of network reliability. We have also developed a model to approximate the reliability of systems with multimode components. Previous research on reliability has been focused on models which assume that each component may be in one of two modes, namely, operative or failed. In real life, a component may undergo degradations in performance before a complete outage, and will therefore operate in more than two modes. More recently, we have developed the Cause-based Multimode Model (CBMM), which allows one to consider failure dependencies of components which are subject to degradations. The model is very flexible and general and has physically meaningful parameters. Practical methods to approximate and

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bound network reliability and performance measures have been developed, based on a state enumeration approach. Most recently, we have developed a path-based approach to efficiently approximate reliability of systems having a path structure. Tests on representative examples have shown that the path-based approach can reduce the processing time by orders of magnitude.

Research Objectives

The goal of our research program is to develop practical models and efficient algorithms to analyze and evaluate the reliability/availability/maintainability of complex systems in which component failures are statistically dependent and each component is subject to degradations before complete failure.

Accomplishments and Progress

We have concentrated on the performance modeling of networks with dependent and with multimode (or multistate) failures, and on network management algorithms which deal with these failures.

We have developed the Event-Based Reliability Model (EBRM) for the reliability modeling and analysis of real systems in which component failures are statistically dependent. Most existing reliability models assume that system component failures are statistically independent. This assumption, though it greatly simplifies the problem, is often not valid, and the result is usually an overestimation of network reliability. Some researchers have tried to model dependent failures by conditional probabilities with limited success. The major problem is that an exponentially large number of parameters have to be dealt with. The EBRM does not make use of conditional probabilities, but tries to model explicitly the events that cause component failures. Major advantages of EBRM over the traditional use of conditional probabilities include a reduction in the number of parameters to be handled and a physically more meaningful set of parameters. We have shown that the EBRM can be used to represent exactly the same kind of statistical dependencies between component failures as described by any given set of conditional probabilities. This means that the EBRM is a completely general model which can be applied to any kind of failure dependencies.

We have also developed a model to approximate the reliability of systems with multimode components. Previous research on reliability has been focused on models which assume that each component may be in one of two modes, namely, operative or failed. In real life, a component may undergo degradations in performance before a complete outage, and will therefore operate in more than two modes. Since it has been proved that the exact calculation of system reliability (even for two-mode models) is an NP-complete problem, we have developed an approximation method to calculate

this reliability measure. This method requires us to work with the states of the system in order of decreasing probability. An algorithm ORDER-M has been developed to generate these states in the proper order.

More recently, we have developed the Cause-based Multimode Model (CBMM), which allows one to consider failure dependencies of components which are subject to degradations. The model is very flexible and general and has physically meaningful parameters. Practical methods to approximate and bound network reliability and performance measures have been developed, based on a state enumeration approach. The methods are very efficient when components are reliable – which is the case in most real systems – because only a small fraction of the total number of states need be considered to achieve a very good approximation.

Most recently, we have developed a new algorithm to enumerate the states of systems having dependent failures and degraded components, which requires less computing time and memory space. We have also developed a path-based approach to efficiently approximate reliability of systems having a path structure. A system has a path structure if we can identify subsystems called paths such that the system is working if and only if there is at least one working subsystem. This assumption is usually applicable, since most real systems exhibit a path structure. Tests on representative examples have shown that the path-based approach can reduce the processing time by orders of magnitude. The Cause-based Multimode Model and the solution methods are detailed in publications #1, #2 and #3.

Research Personnel

Principal Investigator - Victor O. K. Li
Graduate Research Assistant - Khiem Le

Publications during this reporting period

1. Le, K.V. and Li, V.O.K., "Modeling and Analysis of Systems with Multimode Components and Dependent Failures." *IEEE Trans. on Reliability*, Vol. 38, No. 1, April 1989, pp. 68-75.

2. Le, K.V. and Li, V.O.K., "Efficient Enumeration of Most Probable States for Systems with Dependent Failures and Multimode Components." Submitted for publication, 1989.

3. Le, K.V. and Li, V.O.K., "A Path-based approach for analyzing Reliability of Systems with Dependent Failures and Multimode Components." Submitted for publication, 1989.

4. Le, K.V. and Li, V.O.K., "Modeling and Analysis of Systems with Multimode Components and Dependent Failures," *Proc. IEEE INFOCOM*, Ottawa, Ontario, Canada, April 1989.

5. Choudhury, A.K. and Li, V.O.K., "A New Reliability Measure for Computer Networks," *Proc. IEEE TENCON*, Bombay, India, November 1989.